Ice Island Study

Final Report

MMS Project #468

APPENDIX A

Prepared for:

Minerals Management Service
US Department of the Interior

Prepared by:

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C-CORE Report:

R-05-014-241v1.0
August 2005

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FLOATING ICE - OTHER

FENCO CONSULTANTS LTD.
CLIENT: SUN OIL COMPANY LIMITED
REPORT DATE: May 16, 1975

Ice Platform Construction Resolute Bay NWT November – December 1974

Overview:

The test program called for ice platforms to be built by freezing thin layers of ice about 100' offshore in the bay area at Resolute. Four of the platforms were 400 ft. by 300 ft. and required 40 inches of ice buildup. The remaining platform was 400 ft. square with 15 inches of built-up ice. Before work teams arrived, a few days were spent surveying the pads and arranging equipment. The drawing in Appendix I shows the dimensions of the pad and the location of depth stakes, thermistor banks and pump holes.

A number of Flygt pumps of 500 gpm capacity were available with lengths of 4 inch ID hose. However, only two pumps were used at a time. Enough hose was attached to the pumps to reach the whole flood area from four holes spaced out over the pads. Power plants and shelters were placed around the flooding area to provide power and light.

Stakes with tape measures were placed in the pads to measure built-up ice thickness. About twenty stakes were placed on each pad at places where depth measure would be important.

Three thermistor probes were prepared and placed on the pads. Each probe had thermistors spaced out from below the natural ice to the top of the built-up ice.

When further personnel arrived, flooding was begun and was continued mostly on a twenty-four hour basis until the required ice had been made. Different methods of flooding were used with varying degrees of success. However, periods of warm weather during flooding made progress slow.

Besides reading thermistors and thicknesses regularly during flooding, FENCO personnel took cores for salinity, density and visual inspection and performed strength tests in the ice. Also, weather information was gathered for comparison with growth rates. Data obtained is included in various forms in the appendices.

Introduction:

Ice Buildup

An average buildup rate of 1.4 inches per day was achieved for this project. The pumps performed satisfactorily when they were kept submerged. Metal fittings tended to freeze up and it was necessary to bring the hoses into a heated shelter when they were not in use. Warm temperatures and the logistics of flooding a large area were the main factors contributing to the late completion date. Our experience is that an average of 3 inches per day buildup is possible at temperatures below -30°F. Near the end of the flooding program, the centre pad thicknesses were at or above the required thickness whereas localized areas, particularly around the sides, required some 10 inches of buildup.

On the 3rd of November 1974 the natural ice thickness was approximately 20 inches with the variance increasing from pad X to D. The mean thickness achieved on December 6, 1974 is as follows:

Pad A:	60 inches
Pad B:	61 inches
Pad C:	60 inches
Pad D:	63 inches
Pad X:	34 inches

It is anticipated that there was little or no natural ice growth underneath the flooded areas during the period of Nov. 3 to Nov. 30/74. A natural ice growth of 10 inches per month is predicted for December and January.

An attempt was made to correlate the buildup rates to a theoretical development. During the initial floods, warm temperatures and the insulating effect of snow prevented any freezing of the underlying layer. In the latter stages of the flooding program when the temperatures were conducive to freezing, the pad centres were complete. The total buildup rates were low although there was considerable growth around the extremities. It is our experience that winds beyond 10 mph have a mitigating effect such as blowing snow. In any one day, the buildup varied between stake locations. Therefore the lack of correlation is understandable because controlled experiment results from a construction engineering project of this magnitude are difficult to obtain.

Ice Temperatures

During the course of flooding, the temperature near the surface was kept below -10°C to prevent excessive heating. The temperature graphs show the gradient stabilizing to a linear gradient from an average ambient air temperature at the surface to a -1.7°C at the ice-water interface. Nevertheless, the top foot will be sensitive to ambient air temperature fluctuations.

Ice Salinity

The salinity measurements of the built-up ice gave an average of 20°/oo and were highly variable, from a low of 10°/oo to 33°/oo. The average salinity of the built-up sea ice near the surface is approximately 23°/oo. We would expect this salinity to be equal to that of pump water samples (27°/oo) but apparently the high salinity brine is lost during the course of taking a core. Significant brine drainage did not occur during flooding.

Ice Density

The computer average density of sea ice was 0.92 gm/cm^3 with a standard deviation of 0.054.

Ice Strength

Values for confined and unconfined compressive strengths were obtained by circular and triangular plate tests respectively. The results give a confined compressive strength of 2,047 psi for natural ice and 1,911 psi for built-up ice. Unconfined strengths are 724 psi for natural and 927 psi for built-up ice.

In addition, values for the modulus of elasticity were computed to give 2.1 x 10^5 psi and 1.35 x 10^5 psi for natural and built-up ice respectively.

FENCO CONSULTANTS LTD.
CLIENT: SOHIO PETROLEUM COMPANY/ BP-ALASKA PRODUCTION DIV.
REPORT DATE: July 12, 1979

Reindeer Island Floating Ice Road Preliminary Report Vol. 1

A 14-mile ice road was constructed at Prudhoe Bay for Sohio-BP Alaska Product Division of Sohio Petroleum Company.

A 7-mile section of the ice road floating on sea water connected the shore and Reindeer Island over a water depth of as much as 30 feet. Two miles offshore, a branch road led to an artificial gravel island. This island was constructed through the use of the ice road to haul gravel. Within a 3-week period, 105,000 cyd of gravel was hauled over the road using 75-ton heavy gravel trucks. This meant trucks passed any given point on the ice road at the rate of one every 3 minutes.

The main construction of the ice road itself was accomplished within 4 weeks. Ice was built up from 2 feet natural ice thickness to 6 feet artificial ice thickness over a width of 100 feet with an additional 50-foot taper width to natural thickness.

During and after construction of the road, a wide range of ice testing and quality control was performed, several methods of flooding were investigated. Studies and analyses were made on flooding methods, pump types and economical aspects.

Based on experience gained from previous FENCO projects and the above project, various road tests were performed, essentially resulting in more frequent and rapid travel over the floating ice road than has been considered possible.

Two drilling rigs were moved over the road with weights up to 350 tons during transport. One rig was set up on Reindeer Island and the other rig on the artificial gravel island. No accidents or failures on the floating ice road have occurred. The ice road was maintained in good condition so that the rigs received continuous truck service during the entire drilling period.

FENCO CONSULTANTS LTD., represented by Dan Masterson and Raimund Haspel, was responsible for the design and road performance. Laying out the ice road, monitoring and consulting during its construction was given by Lewellen Arctic Research and FENCO CONSULTANTS. After the completion, Clyde Bastian and Raimund Haspel, both from FENCO CONSULTANTS LTD., took turns being on site continuously for road inspection, ice quality control, supervision of maintenance work and general consulting in road use.

Data of construction, road testing and of some costs were collected and evaluated in the FENCO office in Calgary, Alberta. This report represents the first preliminary investigation of all operations and observations on the Reindeer Island Ice Road.

Sandwell

FENCO CONSULTANTS LTD.
CLIENT: SOHIO PETROLEUM COMPANY/BP-ALASKA PRODUCTION DIV.
REPORT DATE: September, 1979

Reindeer Island Floating Ice Road Vol. 3 Field Data Summary

Overview:

Completed report contains all raw information from the field.

1. Ice Thicknesses from Stakes
2. Ice Thicknesses from Profiles
3. Ice Thicknesses from Borehole Jack Tests
4. Borehole Jack Tests
5. Prudhoe Bay Weather Data
6. Reindeer Island Weather Data
7. Ice Temperatures
8. Tides

FENCO CONSULTANTS LTD.
CLIENT: GULF CANADA RESOURCES INC.
REPORT DATE: 1981

Pack Ice/ Rubble Field Interaction Study – Issungnak 1980

Overview:

This report describes the results of a program to study the interaction between moving pack ice and ice rubble, which had surrounded Issungnak Island during the winter 1979-80. Issungnak Island is an artifical gravel island built to serve as a drilling pad for hydro-carbons in the Beaufort Sea north of Pullen Island in the Mackenzie Delta.

Esso and Gulf conducted this study program in co-operation with ice specialists from government and the consulting sector. Among these was FENCO CONSULTANTS, which was in charge of some of the field observations, ice testing, conducting various types of photography and writing this report.

The report discusses environmental conditions and how the rubble around Issungnak had formed. Furthermore the field study program is explained together with the applied techniques and the results from these. A model of an ice sheet failure in flexure was developed and the safety of Issungnak Island investigated.

Introduction:

Some principal results of the Issungnak Study Program are as follows:

1. General

Issungnak Island was sufficiently stable to withstand all effects of ice impact during the winter 1979-80.

2. Shape

Around the circular island formed an elliptically shaped ice rubble field with its major axis 1500 m long in NW direction and its 800 m minor axis. The island itself was located off centre of the ellipse to the SE.

3. Rubble Field

The ice rubble showed in its profiles, ridge heights up to 11 m and keel depths greater than 19 m. The texture of the ice rubble was 26% consolidated ice, 12% voids, 34% hard ice blocks and 28% slush or soft ice. The latter two changed during the winter to 13% and 48%, respectively. Large areas of the rubble were found grounded up to 300 m away from the island.

An analysis of ice rubble block sizes revealed average dimensions of 0.46 x 1.0 x 1.5 m.

FENCO CONSULTANTS LTD.
CLIENT: GULF CANADA RESOURCES INC.
REPORT DATE: 1981

Pack Ice/ Rubble Field Interaction Study – Issungnak 1980

4. Photography

Various types of photography were used to study the ice rubble: Time-lapse, hand-held and aerial photography and movie. Time-lapse and aerial photographs showed no long term ice movements during the winter months. Hand-held photos indicate a great variety of observed ice features. A movie showing ridge building in ride-up and ride-downs of an ice sheet documents well ice rubble formation of the early winter season.

5. Ice Strength Tests

Confined compression tests with a FENCO borehole jack showed 15.3 MPa in average and a modulus of elasticity of about 770 MPa.

6. Failure Model Analysis

For a flexural failure mechanism, which was widely observed in the rubble field, a model was derived to calculate ice forces and ice pressure. As an example, for a 30 cm thick ice sheet riding up a 60° rubble slope, a force of 60 kN per metre width of ice was found. The corresponding ice pressure was figured as 200 kPa. An energy of 54 kJ would break the ice into blocks similar in size to those found in the rubble. These calculated results were considered not critical to island stability, except for severe ice push on top of the island.

FENCO CONSULTANTS LTD.
CLIENT: SOHIO CONSTRUCTION COMPANY
REPORT DATE: October 13, 1981

Offshore – Ice Road System Sag Delta and Challenge Island

Overview:

During the winter season 1980-81 a network of ice roads was built in two separate areas of the Beaufort Sea near Prudhoe Bay, Alaska. This Report describes and documents the construction and gives recommendations for future construction.

In the Sag Delta region an 8.5 mile grounded ice road was constructed from the East Dock in Prudhoe Bay along the coast line to a point west of Howe Island. In addition, two floating offshore spurs each approximately 1.5 miles in length, were built to gravel drill pads identified as Sag 7 and Sag 8. A grounded spur about 200 yards in length was connected to Sag 5 on the southerly most Niakuk Island.

In the area of the Maguire Island chain a floating ice road 3.5 miles in length was built from Challenge Island to Point Gordon on the mainland. An airplane landing strip, 2,000 ft. long on floating ice, was placed near the southwest end of Challenge Island.

The construction was extended in spring 1981 by a layout of ice roads for gravel haul eastwards to Alaska Island, and from there to Point Hopson.

The total length of ice road construction was 7 miles of floating road, and 9 miles of grounded ice road not including the gravel haul roads, which were about 15 miles in total over floating, partly grounded ice and tundra.

The ice road network was owned by Sohio Alaska Petroleum Company and built by Sohio Construction Company as General Contractor. Subcontractor was Northwestern Construction Company Inc. FENCO CONSULTANTS LTD was retained by Sohio for design and monitoring the ice road construction and writing this Report.

The Sag Delta and Challenge Island ice road network was considered as a successful transportation system for rig haul and service. The construction was well within time schedule and budget limits. The ice roads proved to be a competitive and economic solution for arctic offshore winter operations at the North Slope of Alaska.

Sandwell

FENCO CONSULTANTS LTD.
CLIENT: SOHIO CONSTRUCTION COMPANY
REPORT DATE: November-December, 1981

Sag Delta Ice Road System Nov/Dec 1981

Overview:

Various pictures showing Dale Payne pump tests (August-September, 1981) and the Sag Delta Ice Road System. (No narrative)

Sandwell

FENCO CONSULTANTS LTD. **CLIENT: SOHIO CONSTRUCTION COMPANY** **REPORT DATE: November-December, 1981**
Sag Delta Ice Road System Nov/Dec 1981

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FENCO CONSULTANTS LTD. CLIENT: SOHIO CONSTRUCTION COMPANY REPORT DATE: November-December, 1981
Sag Delta Ice Road System Nov/Dec 1981

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FENCO CONSULTANTS LTD. CLIENT: SOHIO CONSTRUCTION COMPANY REPORT DATE: November-December, 1981
Sag Delta Ice Road System Nov/Dec 1981


FENCO CONSULTANTS LTD.
CLIENT: TRI OCEAN ENGINEERING
REPORT DATE: December 31, 1981

Rea Point Dock Design Criteria (Draft)

Overview:

Expected ice forces on the dock have been tabulated and a preliminary dynamic analysis of a free standing sheet pile cell conducted to examine the possibility of using time average rather than peak ice crushing forces.

Ice pile-ups, downdrag and uplift loads and direction of loading as well as forces driving the ice sheet are discussed. The maximum wave height, although not discussed in the draft, has been checked. Since the shoal area is deeper than originally thought the maximum wave height should probably be increased to 3.8 or 4 m form the 3.2 originally presented in the Feasibility and Budget Cost Estimate report.

FENCO CONSULTANTS LTD.
CLIENT: SOHIO CONSTRUCTION COMPANY
REPORT DATE: July 16, 1982

Sag Delta Offshore Ice Road System

Overview:

This report is an account of construction procedures, techniques and observations of the Sag Delta Ice Road Construction during November and December of 1981, east of Prudhoe Bay, Alaska. The construction involved two 1.5 mile floating ice road sections offshore of the Sag Delta and an 8.5 mile access shore road over mostly grounded ice. The floating offshore sections were built in about 5 weeks time using flooding and freezing techniques to build up 3 ft. of ice on top of 2 ft. of natural ice. The total thickness was designed to carry rig haul and service vehicles to artificial gravel islands, Endeavor and Resolution Island, called briefly Sag 7 and 8.

New flooding equipment and strict project control assisted in improving typical buildup rates and maintaining an adequate level of ice quality run though a slightly warmer winter season was experienced than in years before. The shore road was cleared wide enough to serve required traffic needs with typical snow removal equipment in only a few days.

In addition to the roads, a snow and ice ramp was built to Sag 8 and rig storage areas were established.

The Sag Delta ice road construction was critically reviewed with suggestions for improvements for future ice roads. Ice related data were evaluated and documented in tables and figures. Work specifications were briefly reviewed to facilitate future planning of similar ice road structures.

In general, it was found the 1981 construction of the Sag Delta Ice Road System was a success and an improvement in most aspects. It compared to previous ice road constructions, in 1981 there were higher buildup rates, a shorter road construction and a more economical use of man-power and equipment.

FENCO CONSULTANTS LTD./ LAVALIN
CLIENT: SHELL OIL COMPANY, ALASKA OPERATIONS
REPORT DATE: September 8, 1982

Seal Island Floating Ice Road Report on Construction and Monitoring

The report contains an analysis and summary of data and sketches taken by FENCO field personnel from December 1981 to April 1982.

The construction consisted of about 10 miles of ice road of which 3.5 miles were floating offshore of the Barrier Islands at the North Slope of Alaska. The ice road was built to serve as access for a gravel haul to an offshore location designated for construction of a gravel island. Ultimately, the island is scheduled to support offshore drilling operations for hydrocarbons by Shell Oil Company.

The ice road construction started in December 1981. Flooding and freezing techniques were used to thicken the floating ice road sections from about 3.5 ft. up to a 9 ft. target thickness. The width of the road was staked out as 150 ft. whereas the flooding width reached more or less 350 ft. After construction, the road was kept free of snow for traffic for the rest of the winter.

The average daily ice buildup due to surface flooding as measured with buildup stakes was 1.10 in./day. The average daily natural ice growth measured 0.3 in./day over the construction period. Two contractors supplied flooding equipment both using rolligon vehicles carrying, or having mounted, 14 in. to 18 in. diameter ice drill and water pump systems. The system with encased pumps was by far superior to the unencased pumps because it experienced only minor break-downs and offered a 5000 GPM output without any water loss caused by draining back into the ocean.

The ice quality was tested through measurements of ice strength, salinity and temperatures. The quality was sufficient for the purpose of the road but could have been even better if the weather temperatures had been more consistently cold as was observed in previous years.

During the road use, static and dynamic load tests were carried out with typical loads such as belly dump and B70 gravel trucks. Less than 1 in. deflection was measured and the dynamic amplification of this did not exceed a multiple of 1.5. This is in accordance with previous experience on similar ice roads.

A documentation of all data is included in this report accompanied with sketches and drawings. Photographs were added to illustrate construction events, equipment and situations. A chronological list of field notes made by FENCO personnel also represents a part of this report. The Appendix contains tables and lists which were produced with the help of a computer program.

FENCO CONSULTANTS LTD.
CLIENT: SHELL OIL COMPANY, ALASKA OPERATIONS
REPORT DATE: December 1981 to April 1982

Seal Island Ice Road and Gravel Island Construction Dec 1981 – Apr 1982

Overview:

This report contains various photographs of Seal Island's Ice Road and Gravel Island.

CATCO Rolligon R85 Flooding Unit

FENCO CONSULTANTS LTD.
CLIENT: SHELL OIL COMPANY, ALASKA OPERATIONS
REPORT DATE: December 1981 to April 1982

Seal Island Ice Road and Gravel Island Construction Dec 1981 – Apr 1982

GSL Pump Hole Drain Water

Section of Flooded Ice Road

FENCO CONSULTANTS LTD.
CLIENT: SHELL OIL COMPANY, ALASKA OPERATIONS
REPORT DATE: December 1981 to April 1982

Seal Island Ice Road and Gravel Island Construction Dec 1981 – Apr 1982

Fenco Road Survey

Ice Profiling with electric drill

FENCO CONSULTANTS LTD.
CLIENT: SHELL OIL COMPANY, ALASKA OPERATIONS
REPORT DATE: December 1981 to April 1982

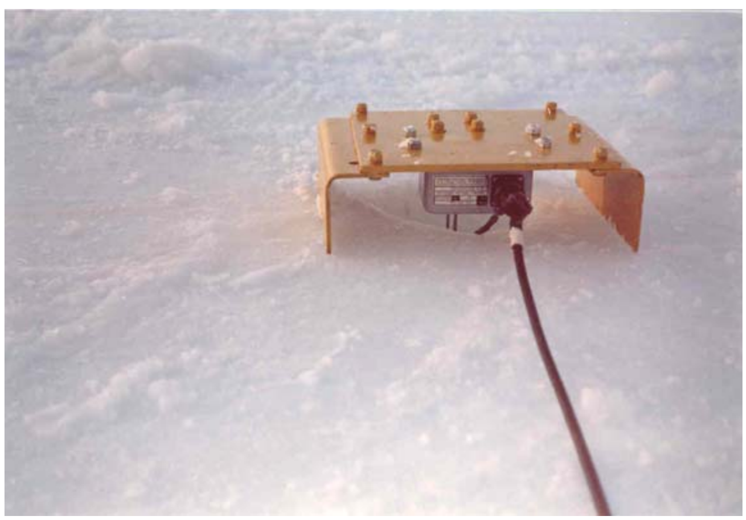
Seal Island Ice Road and Gravel Island Construction Dec 1981 – Apr 1982

Deflection measurements with level and rod

FENCO CONSULTANTS LTD.
CLIENT: SHELL OIL COMPANY, ALASKA OPERATIONS
REPORT DATE: December 1981 to April 1982

Seal Island Ice Road and Gravel Island Construction Dec 1981 – Apr 1982

Ice coring and sampling for salinity measurements



Dynamic deflection gauge installed over an ice hole

FENCO CONSULTANTS LTD.
CLIENT: SHELL OIL COMPANY, ALASKA OPERATIONS
REPORT DATE: December 1981 to April 1982

Seal Island Ice Road and Gravel Island Construction Dec 1981 – Apr 1982

Edge of flooded ice and designated island location

Widening of the ice hole with a Ditchwitch cutting machine (equipped for buoyancy tanks in case of break-in)

FENCO CONSULTANTS LTD.
CLIENT: SHELL OIL COMPANY, ALASKA OPERATIONS
REPORT DATE: December 1981 to April 1982

Seal Island Ice Road and Gravel Island Construction Dec 1981 – Apr 1982

Gravel is pushed into ice hole using dozers

Backhoes catch cut ice blocks out of the water

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FENCO CONSULTANTS LTD.
CLIENT: SHELL OIL COMPANY, ALASKA OPERATIONS
REPORT DATE: December 1981 to April 1982

Seal Island Ice Road and Gravel Island Construction Dec 1981 – Apr 1982

Ice blocks loaded on end dump trucks

After surfacing of the gravel, trucks drive onto the new island to unload

Sandwell

FENCO CONSULTANTS LTD.
CLIENT: SHELL OIL COMPANY, ALASKA OPERATIONS
REPORT DATE: December 1981 to April 1982

Seal Island Ice Road and Gravel Island Construction Dec 1981 – Apr 1982

Typical Euclid B70 Gravel Truck

Typical Belly Dump Gravel Truck

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FENCO CONSULTANTS LTD.
CLIENT: SHELL OIL COMPANY, ALASKA OPERATIONS
REPORT DATE: December 1981 to April 1982

Seal Island Ice Road and Gravel Island Construction Dec 1981 – Apr 1982

Road Maintenance (grader followed by a snow blower)

Gravel Pit for Seal Island Construction

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FENCO CONSULTANTS LTD.
CLIENT: SHELL OIL COMPANY, ALASKA OPERATIONS
REPORT DATE: December 1981 to April 1982

Seal Island Ice Road and Gravel Island Construction Dec 1981 – Apr 1982

Loading Gravel Trucks at Pit Site

FENCO CONSULTANTS LTD.
CLIENT: SOHIO CONSTRUCTION COMPANY
REPORT DATE: June 22, 1983

Thetis Island Ice Road Volume 2 Construction and Monitoring Report

During the winter season 1982-83 an ice road was built in Harrison Bay of the Beaufort Sea west of Prudhoe Bay, Alaska. This report documents and describes the construction and use of the ice road and gives recommendations for future ice road projects. A previous report of December 10, 1983, covers design and construction specifications for the road.

The Thetis Island ice road was 8.1 miles long offshore of which almost 3 miles was grounded. The road ran between a point onshore southeast of Oliktok Point to the southwestern tip of Thetis Island. At this location a grounded ice pad was constructed to store the bulk material from the gravel haul.

Construction began on January 10 and was completed on February 20. The gravel haul took place between February 23 and April 14, 1983, with 1.25 million cubic yards of material hauled.

The ice road project was a success with a serviceable transportation route available throughout and beyond the gravel haul period.

RECOMMENDATIONS

In the following discussion several recommendations are made to improve ice road construction and use.

The unfortunate 2 to 3 week period of warm temperatures in early February caused serious concerns of completing the ice road on time. The amount of gravel required to be hauled by the critical completion date of April 15, made the ice road construction completion date also a very specific and crucial point in the construction schedule. It is recommended that the acquiring of permits, issuing of contract awards and scheduling of construction, wherever humanly possible, be done sufficiently ahead of time in order to allow an early start of construction. This will assure a weather safety factor in the schedule. This warm period of weather has occurred on the North Slope in late December to early February over the last five or so years.

Thetis Island Ice Road, because of the pressure ridging and environmental concerns, required considerable time to reconoitor for location, investigate for ice thicknesses, check water depths, and select proper curve alignments. The ice engineer had an appreciable input into this phase of the work. It would save time and expense if the ice engineer would arrive early on the site by at least one week. Some realignment of the road was necessary at the southeast tip of Thetis Island based on the engineers decision to select the best location to cross the pressure ridge. If the engineer had been on site before layout of the initial centreline, realignment of 2 miles of the ice road would have been avoided.

It is felt that road alignment was probably more precise than necessary. Location of design width stakes, curves and centreline alignment can be laid out with less accuracy. In some cases this can be accomplished by pacing off or aligning by eye thus reducing the time and man-hours required for layout. An initial alignment by instrument is required for long roads.

Densely packed snow drifts encountered during early construction were difficult to break up and properly saturate with sea water. It has been customary when starting an ice road to drag down drifts and moderate snow cover and to flood this snow into the first stages of the ice road. This saves both time and the significant cost of snow removal equipment. It provides for a large buildup during the first floodings. It also eliminates drifting and ice load caused by the displaced snow being spread along the sides of the road.

In view of the difficulties encountered with the dense hard packed drifts at Thetis Island this past year it is recommended that if similar snow conditions on future work exist, complete snow removal to a safe distance from the design width be ordered prior to flooding.

The bridging designed to cross the pressure ridge worked well to provide a high speed access over the ridge and similar techniques and equipment are recommended for use in future years. Procedures to level the pressure ridge using graders and 'yoyoing' with a drag proved very effective without requiring much time or expensive equipment. Wide flooding of a ridge or tidal crack crossing is also recommended in light of the rerouting which was required. This year the initial temporary rig mat crossing, while functional, was rough. It required slow vehicle speeds and attracted snow drifts due to a high profile. The steel plate crossing proved excellent. The steel plates were easy to place, required minimum maintenance, and slowed the traffic much less than the rig mats. In addition, the low profile of the sheets caused minimal drifting problems.

The problems encountered with brine pockets are difficult to avoid as they are essentially the result of flooding operations during abnormally warm weather. As the construction schedule is usually rigid and tight, suspension of flooding activities during periods of warm weather is difficult to justify. Large brine pockets are a sign of too much or too fast flooding during a time of warm temperature and changes in the flooding schedule must be immediately put into effect. Large brine pockets should not be allowed to form but should they occur, the general condition of the road can be determined through a closely spaced profile. It would, however, not be possible to locate all the brine pockets that might exist. Given time and a lowering of temperatures, the brine will drain through the ice and/or freeze.

The reflection of the stake reflectors on the profile stakes obscured viewing of the station numbers by their brilliance. It is recommended that reflectors be separated from the station marker sign by 18 in. A reflector on each side of the profile stake is also recommended.

Snow removal activity on the part of the gravel haul contractor was frequently less than desirable especially in the creation and neglect of berms along the road edge. This was contrasted at other times with a considerable effort at snow removal especially following storms. It is recommended that the contractor responsible for snow removal be impressed, prior to the start of the work, with the required fulfillment of the snow removal specification.

Some problems were encountered in communicating to the haul contractor the importance of proper vehicle use on the road and the safety of the ice for equipment operations. Occasionally, considerable pressure was required on the part of Sohio Construction Company to ensure that unsafe conditions did not occur with respect to the contractor's use of the ice road and surroundings. It is recommended that the required compliance with certain limitations in loading, use of proper vehicle configurations and other regulations dealing with the structural safety of the ice road be included in the haul contractor's contract.

It is recommended, for the protection of Sohio's interests, that a provision be made in any contracts drawn with respect to use of an ice road that the contractor be held responsible if any deemed unsafe activity with reference to the ice occur during a project and that Sohio have ultimate authority in determining the proper solution to this unsafe condition. Such a provision would clear up potential disputes at the contract stage and help prevent unsafe activity with regard to the ice.

Engineering monitoring of any ice road during a major gravel haul is recommended. At Thetis Island, in many cases, this monitoring of the ice road by the ice engineer prevented increased damage to the road, this through recommendations for repairing cracks, changing traffic patterns, evaluating vehicle loading and vehicle configurations and other quality control and road maintenance procedures.

tti GEOTECHnical resources ltd.
CLIENT: SOHIO PETROLEUM COMPANY, DALLAS, TX
REPORT DATE: AUGUST, 1984

SSDC Bow Rubble Generator Ice Island Construction

Overview:

The traditional method of construction of work pads has been by the use of flooding periodically in layers of up to 50mm and allowing these to freeze. While this method works well when thicknesses in the order of 5m are required, greater thicknesses require an excessive amount of time. To obtain accelerated growth of ice the spraying concept was developed. To compare both methods consider a 5cm layer of water on the ice surface contains the equivalent of 1.5 million 4mm drops/m^2 of surface area. This yields a drop surface to water surface area ratio of 75 to 1. As heat transfer is in direct proportion to surface area this represents a very significant increase in freezing rates.

Ice rubble is generated when thin moving ice is obstructed. Laboratory experiments have shown that with the proper mechanism this rubble can be grounded in 30' of water. While neither of these systems is considered satisfactory alone, a combination of both could be developed for the construction of ice islands. To demonstrate the feasibility of the system Sohio decided to build an ice island using this technique.

To produce the rubble a number of "rubble generators" were considered. Based on availability, scheduling and location the bow of the S.S.D.C. was chosen. The bow was modified to generate rubble and also to accommodate a generator building, moonpool and instrumentation building. The bow also provided for a platform from which to spray the rubble. Two fire monitors powered by two 100 h.p. pumps were mounted on the bow. Fig. 2.1.2 shows the finished structure.

Site Location

The bow was towed from McKinley Bay to a point 13km north of Atkinson Point and sunk in 13m of water. Fig. 1.2.1. This site was selected as it had the correct depth of water for the bow to act as a rubble generator. The ice traps are 12.7m from the sea-bed. This location was also in a zone of anticipated first-year ice movement.

Design Philosophy

The initial consideration is the size of the island to be constructed. Using the 100 h.p. pumps with fire nozzles attached spray could be sent over a distance of 60m. Since spraying will be done from a central location the shape of the island will be circular in plan. A pad of diameter 120 m is also the minimum required for actual drilling. If this island were to be utilized to accommodate a drilling rig then prevention of lateral movement would be of prime importance. Therefore the island must have sufficient mass to resist sliding. The force to be resisted is calculated by assuming an ice sheet 2 m thick by 140 m wide exerting a pressume of 1 MPa (typical ice island design) against the island.

Sandwell

tti GEOTECHnical resources ltd.
CLIENT: SOHIO PETROLEUM COMPANY, DALLAS, TX
REPORT DATE: AUGUST, 1984

SSDC Bow Rubble Generator Ice Island Construction

Schedule of Events

October 16, 1983	S.S.D.C. Bow towed to site and sunk in 13 m of water
December 03, 1983	Spraying from structure commenced
January 77, 1983	Spraying from structure discontinued
January 19, 1983	Spraying from Kigoriak initiated
January 24, 1983	Construction terminated

Recommendations:

The largest horsepower pumps commensurate with available power should be used. The exit velocities from the 100 h.p. pumps and the 1600 h.p. were both in the region of 50 m/s. However the water from the larger pump reached a greater elevation. This is due to the larger volume of water pumped and also the shape of the jet which in turn is a function of the nozzle design. Any monitor designs should incorporate turning vanes and swirl damping devices with the overall objective of any monitor/nozzle design being maximum casting distance with minimum break up of the jet until it reaches the apex of its trajectory.

If spraying is to be done from a central location as was done from the rubble generator a number of improvements could be made. The main monitor caused quite a lot of ice build up on the structure especially when spraying across wind. A solution to this problem would be to place four monitors on the structure, one at each corner below the top deck. These would all be interconnected thus giving more flexibility to the system. A typical layout is shown in Fig. 6.1.1. Experience has shown that when the wind is predominately from one quadrant it is difficult to get any ice build up in that quadrant. One method of overcoming this problem would be to have a 50 h.p. "mobile" submersible pump. Three well locations with 60m of aluminum pipe would be sufficient for this pump to spray in any location desired. A second method is to have aluminum pipe from the main piping network to monitors located at the extremes of the build up area.

All swivels on the monitors should be automatic, controlled by limit switches and protected from the elements. Limit switch settings, pump starting switches and valving would all be controlled from an observation deck above the four main monitors.

If a central structure was not to be used then a system similar to that aboard the Kiroriak should be utilized again using the most powerful pumps possible. Without the obstruction of a central structure the efficiency of this system would increase.

Sandwell

tti GEOTECHnical resources ltd. / Golder & Associates
CLIENT: SOHIO PETROLEUM COMPANY, Dallas, TX
REPORT DATE: April, 1985

Spray Ice Island Preliminary Data Package

Overview:

The object of the project was to obtain more information regarding techniques of spraying using high pressure pumps and also to provide data and analysis required by industry for the design and construction of working grounded spray ice structures.

The 350 foot island was constructed between February 18, 1985 and March 18th, 1985. The location of the island as shown in Figure 1 was selected as it had the desired water depth and was also accessible by an existing ice road. On completion this island had an average thickness of 46' (Figure 3). To facilitate testing part of the island was levelled as shown in Borehole location sketch. Data collected includes weather, ice build up, volume of water pumped and densities of 16 cores. Samples of spray patterns are also included. The temperature profiles during construction are not available at this time.

Preliminary uninterpreted data obtained during the post construction field program between April 02, 1985 and April 11, 1985 is also presented. These data include the deep sampled borehole records, most of the CPT data and a selection of the pressuremeter test data. Flatjack, borehole jack and laboratory test data are also summarized.

Sandwell

tti GEOTECHnical resources ltd. / Golder & Associates **CLIENT: SOHIO PETROLEUM COMPANY, Dallas, TX** **REPORT DATE: April, 1985**
Spray Ice Island Preliminary Data Package
The purpose of this data package is to provide the initial raw data to the study partners for their own evaluation. To date detailed interpretation and checking/correlating of the data has not been carried out, but is currently taking place. A further purpose is to provide sufficient background for planning of the additional laboratory testing to be carried out to complete the program.

Sandwell

GEOTECHnical resources ltd. / GOLDER & ASSOCIATES CLIENT: SOHIO PETROLEUM COMPANY et al. REPORT DATE: September, 1985
Construction, Testing & Monitoring Spray Ice Island (Appendices)
Overview: **Report includes raw data on Ice Build-Up Data, Weather Data, Spray Patterns, Details of Field Equipment, Diary of Field Program, Laboratory Test Results (Natural Samples), Cone Penetration Tests, Pressuremeter Tests, Flatjack and Borehole Jack Tests, Tabulated Slope Indicator, Sondex and Thermistor Data.**

INTRODUCTION

The design of an ice platform or ice road is based on two criteria. These are:

1. limiting flexural stress in the ice to a safe level
2. limiting long term deflection to less than available freeboard.

Many platforms and roads have been designed based on these criteria and they have all been safe and useful structures.

DEFINITION OF TERMS AND SYMBOLS

σ	stress (kPa)
σ_{max}	maximum stress (kPa)
ν	Poisson's ratio (0.3) assumed
b	loading radius (m)
k	unit weight of water (1000 kg/m^3)
ℓ	stiffness length (m)
h	ice thickness (m)
p	applied load (kN)
E	Elastic modulus (5.52 GPa) assumed
x	distance from x_o to point of interest (m)
x_o	relative position of the applied load P_o (m)
δ	deflection of the ice sheet (m)
δ_{30}	30 day (long term) deflection (m)
P_1, P_2, P_3	applied loads (kN)
x_1, x_2, x_3	distances from point of interest of P_1, P_2, P_3 (m)
E*	long term elastic modulus (MPa)
ℓ*	long term stiffness length (m)
F	freeboard (m)

STRESS ANALYSIS

Stress levels in the ice platform are calculated from the equations for maximum extreme fiber stress of a beam or an elastic foundation. Maximum stress under an applied load, P_1 is given by equation (1).

$$\sigma_{max}=0.275(1+\nu)\ \frac{P}{h^2}\ \log\left[\frac{Eh^3}{kb^4}\right] \qquad (1)$$

The effect of multiple loads is taken into account by using the principle of superposition and noting that the effect of a load applied a distance x from the point of interest is given by equation (2).

$$\sigma_x=\sigma_{max}\quad \exp\left[\frac{-x}{0.691\ell}\right] \qquad (2)$$

The stiffness length, l, of an ice sheet is given by equation (3)

$$\ell = \sqrt[4]{\frac{Eh^3}{12(1-\nu^2)k}} \qquad (3)$$

The total stress at a point A due to loads P_o, P_1, P_2, P_3 ... at distances x_o, x_1, x_2, x_3 ... is evaluated from superposition by equation (4)

$$\sigma_{total} = \sigma_o + \sum_{n=1}^{i} \sigma_n \exp\left(\frac{-x_n}{0.691\ell}\right) \qquad (4)$$

where σ_o, σ_1, σ_2, are evaluated from equation (1).

The ice thickness of the platform is calculated based on limiting total stress, σ_{total}, to 520 kPa which is a proven safe value. The value of ice thickness, h, is adjusted until the combined effect of the applied loads is less than 520 kPa as calculated from equations (1), (2), (3) and (4).

DEFLECTION ANALYSIS

The instantaneous deflection of a beam on an elastic foundation under an applied load, P_1 is given by equation (5).

$$\delta = \frac{P}{8k\ell^2} \qquad (5)$$

To calculate the long term (> 30 day) deflection of the platform, a time-reduced elastic modulus, E^*, is used given by equation (6).

$$E^* = 0.1E \qquad (6)$$

This value for E^* is used in equation (3) and equation (5) to calculate the long term deflection, δ_{30}, from equation (7) and (8).

$$\ell^* = \sqrt[4]{\frac{E^*h^3}{12(1-\nu^2)k}} \qquad (7)$$

and

$$\delta_{30} = \frac{P}{8k\ell^2} \qquad (8)$$

The deflection of the ice platform, σ_{30}, is limited to the available freeboard, F, which is measured or calculated from equation (9).

$$F = 0.1h \qquad (9)$$

Thus the limiting condition for the ice platform deflection is given by equation (10)

$$\delta_{30} \leq F \qquad (10)$$

The long term deflection of the ice platform can also be evaluated by equation (11) which is derived empirically from previous ice platform case histories.

$$\delta_{30} = 0.605F \qquad (11)$$

A SAFE DESIGN

A safe design is calculated based on

$$\sigma_{total} \leq 520 \text{ kPa}$$

and

$$\delta_{30} \leq F \text{ m}$$

The extent of the design area required is predicated on the area of loading from applied loads on the ice platform and the distance from the rig that the ice stresses reduce to a minimal (<10% σ_{max}) level.

GEOTECHnical resources ltd.
CLIENT: BP CANADA INC.
REPORT DATE: February 4, 1986

Marguerite Lake Ice Platforms Detailed Design Report

MARGUERITE LAKE PLATFORM DESIGN

The design of the Marguerite Lake ice platforms was done based on the rig layout and the anticipated loads for Westburne #37 Rig. This rig has been retained to drill these wells. Based on this information, the calculated ice thickness for the platforms is 1.53 m with a radial extent of between 25 and 35 m. Drawings of the ice platform layout and profile are included here. A taper zone of ice thickness decreasing from the design thickness to the natural ice thickness surrounds the design area, an additional 8 m across. A drawing of the layout for Westburne #37 is also included.

Stresses in the ice caused by rig loads are all less than 520 kPa throughout the design area based on the analysis. Available freeboard at design thickness is calculated to be 0.15 m. Long term deflection based on the analysis is between 0.09 and 0.12 m which is safely less than the available freeboard.

Sandwell

GEOTECHnical resources ltd.
CLIENT: B.P. CANADA INC.
REPORT DATE: April, 1986

Marguerite Lake Ice Platforms Final Report

Overview:

ORIGINAL DESIGN

The design of an ice platform is based on two criteria. These are:

1) Limiting flexural stress in the ice to a safe level of 520 kPa.

2) Limiting long term deflection to less than the available freeboard.

A report entitled "Marguerite Lake Ice Platforms Detailed Design Report" was prepared and issued to B.P. Canada on February 4, 1986. This report details the design procedure and equations used in calculation of the ice platform design for the wells at Marguerite Lake.

On January 20, Westburne Drilling was contacted by GEOTECH to obtain rig and component loads for Rig #37 which was to be used for this project. The loads and distribution are shown in Figure 1. Based on this information and the design procedures mentioned, an ice platform 1.53 m in thickness was calculated. The platform was to be egg shaped with a radial extent of between 25 and 35 m. A taper zone of ice thickness decreasing from design thickness to the natural ice thickness surrounded the design area, an additional 8 m across. Drawings of the ice platform layout and profile are shown in Figure 2 and 3. Identical platforms were to be used for each well location and these were identified Pad 12-17, Pad 13-8 and Pad 13-7 following the well designations.

REVISED DESIGN

Difficulties were encountered during the drilling of Well 12-17 (see Section 3) using Westburne Rig #37. These problems were associated with having loads larger than those designed for on the ice pad. It was decided by B.P. and GEOTECH that another rig and a different loading pattern was required for Wells 13-8 and 13-7. A lighter rig, Westburne #40, was selected and loads were determined for it.

At this time, the construction of both Pads 13-8 and 13-7 was complete. Warm weather and operational considerations indicated that further ice build up was not practical. Hence, the rig selection and layout was fitted to the pads already built.

The loads and distribution for Westburne Rig #40 are shown in Figure 4. These loads were independently verified as far as possible to ensure accuracy. These loads and configuration could safely be supported by 1.42 m of ice which was slightly less than the 1.44 to 1.48 m found on each of Pads 13-8 and 13-7. The radial extent of the pads as built was 45 m which was more than required.

The wells at 13-8 and 13-7 were both completed using Westburne Rig #40 and the revised design.

CONCLUSIONS

Construction

Weather conditions prevalent throughout construction were unseasonal, with exceptionally mild temperatures. This adversely affected the build up rates that were achieved. The construction technique used involved dyking the flood perimeter and applying deep (75-100 mm) floods. Warm ($0^\circ C$) ice temperatures were recorded through the ice mass all through construction. This fact and the low (<10%) freeboard values found at the end of construction indicated a non frozen (water) content in the built up ice. A week of cooling after construction was required to freeze the ice mass and achieve the desired freeboard.

Platform Performance

The performance of Pad 12-17 with Rig #37 indicated that accurate, confirmed loads are required from all contractors when operations on the ice are undertaken. A contractor's own estimates are not necessarily reliable.

It is noteworthy that ice platform performance is stable and predictable providing that strict control of load on the ice is ensured.

Special care is necessary in regard to placement and use of support vehicles for rig operations. It is necessary to direct and control these vehicles at all times.

Ice Quality and Testing

Ice temperature, strength and load-deflection behaviour were measured for the ice platforms. This information was essential to the successful completion of the project.

Ice temperatures were important during construction as they indicated the reason for low freeboard values found. The warm temperatures indicated that the ice during construction was of marginal quality. This was tolerated to enable adequate ice to be built in time under the adverse weather conditions. Ice temperatures during drilling were important information to monitor any melting of the pads.

Ice strength information from the borehole jack was important to asses the strength and quality of the pads as built with reference to the design.

Load-deflection information from the load test was very valuable. This data enabled a test trial of platform behaviour to be undertaken before the design loads were placed. This test confirmed the design assumptions and enabled a calibrated prediction of behaviour under the rig loads.

RECOMMENDATIONS

Construction

It is recommended that a change be made in construction procedure especially if adverse (warm) weather conditions prevail during construction. The use of thin (25-50 mm max) flood thickness is desirable without containment dykes as these floods are easier to freeze completely, requiring less time than deep (100 mm) floods. The dykes contain the floodwater and tend to produce deeper floods without careful control of pumping times. Complete freezing of the floodwater is desirable as it would prevent the low freeboard condition found at construction's end and avoid delays required to freeze the built up ice before use.

The equipment used for flooding, small gas powered impeller pumps can be improved upon. The use of larger auger driven pumps is recommended. These pump units can be gas powered or vehicle mounted and run from hydraulic power. This units are currently available in Alberta. These auger pumps will decrease flood time substantially, which promotes built up.

GEOTECH has spray flooding technology and equipment which has proved very successful in the Arctic. The advantage of spray flooding is that substantial improvements in built up rates (50%-100% increase) can be achieved.

A recommended option for well pad construction is the use of spray flooding technology. A large mass of ice can be built in a relatively short period of time.

Build-up of an ice pad can be achieved to a level where the entire structure is grounded (bottom founded). This is a substantial advantage over floating structures as vertical deflections are no longer critical to the design.

With this procedure, it would be possible to build a grounded structure within the construction period.

Platform Performance

In regard to ice loads, it is recommended that a meeting should be held between all contractors, the well operator and any consultants with regard to the scope and details of the project. At this time a rapport can be established and each party can be properly informed regarding to their participation and the completeness of any information that may be required. In terms specifically relating to ice safety, an independent confirmation of all loads to be placed on the ice should be required prior to commitment to the project. It would also be helpful if this meeting also detailed the chain of command and the responsibilities of each party with regard to each facet of the project. This would be particularly helpful if changes in scope of work are required in the field.

It is further recommended that the ice engineer on site have adequate authority to control and direct the loads on the ice. This is particularly important in reference to support vehicles used in well operations.

Ice Quality and Testing

It is recommended that ice quality be tested and monitored during construction and drilling. This is necessary so that design assumptions can be verified and behaviour can be predicted during drilling.

Sandwell

Sandwell Inc.
CLIENT: ARCO Alaska Inc.
REPORT DATE: March 7, 1996

Warthog Ice Structure – Final Design Report

Overview:

This report details the design of a grounded ice island for exploration drilling at ARCO Alaska, Inc.'s Warthog site located in the shallow water of Camden Bay, approximately 100 km east of Prudhoe Bay, Alaska. It will be constructed using ice spraying techniques during the December / January time frame. ARCO Alaska, Inc. contracted Sandwell to design an island which will be capable of resisting the horizontal ice loads from ice sheet movements and be capable of supporting the required vertical rig loads.

A number of design geometries were investigated and a circular plan geometry was chosen as being the most efficient when ice forces, required ice volumes and vertical build-ups were considered.

The general approach for the design was to select the horizontal dimensions of the structure to satisfy the undrained silt shear requirements. Once the overall horizontal dimensions of the structure were selected, the freeboard was then chosen to satisfy the sand friction criteria. A factor of safety of 1.5 has been incorporated in the design. The final geometry was then used to calculate the volumes of spray ice required and the build up times.

The overall advantage of a segmented design, which includes a moat, is that during the construction of the berm in the second stage, spraying can be done down-wind away from the rig from within the moat. For a design not incorporating a moat, spraying would always be performed from the outside perimeter towards the centre, thereby possibly resulting in a larger amount of overspray onto the rig.

The critical design aspects are seabed contact area (dictated by the undrained shear strength of the silt), maximum ice interaction width (determining lateral ice forces), and surcharge weight or volume (determining the sand resistance). The distribution of the surcharge weight among the various parts of the structure can be selected based upon their constructability. This also provides flexibility in the construction process since the total weight of ice is the important factor rather than its precise placement. Thus, the overall structure design is an idealized geometry and considerable deviations are possible while maintaining overall stability. During construction, the final detailed shape will not likely match the design geometry.

Basic Design Parameters

Mean Water depth	12 (ft)
Water density	64 (lb/cu ft)
Spray ice specific gravity	0.62
Spray ice density	38.7 (lb/cu ft)
Design, global ice thickness	6.5 (ft)
Design ice pressure	200 (psi)
Initial ice thickness	2.0 (ft)
Factored, undrained silt shear strength	200 (lb/sq ft)
Sand friction angle	30 (deg)
Factor of safety	1.5
Minimum drill pad radius	300 (ft)
Underwater berm slope	4:1
Above water berm slope	2:1

Sandwell

Sandwell Engineering Inc.
CLIENT: Phillips Alaska Inc.
REPORT DATE: September 29, 2000

McCovey Ice Island – Island Design Report

Overview:

Phillips Alaska, Inc. and its partners intend to construct a grounded sprayed ice island at the McCovey prospect in 36 ft of water approximately 4.5 miles northeast of Reindeer Island and to drill an exploratory well from that island during the winter of 2000/2001. Reindeer Island is approximately 7.5 statute miles northeast of West Dock at Prudhoe Bay Alaska.

Sandwell Engineering Inc. had been retained to design the island and to provide site engineering, quality control during construction and monitoring during drilling. This document addresses the design and principal construction methodology of the island as well as the quality control and monitoring procedure.

The island must be capable of resisting the lateral ice forces and which can be constructed early enough in the winter to allow the rig to be mobilized on-site and safely drill the well and be de-mobilized by early May 2001. The design:

- assesses the risks to the island and the ice supply road from ice movement,
- derives the shear resistance of the island and the lateral ice loads,
- describes in detail the dimensions and material composition of a spray ice island capable of resisting the lateral ice forces and of supporting the drilling rig,
- assesses the pumping equipment required to construct the island using past island experience and a computer model,
- outlines a general construction and spraying procedure and assesses the feasibility of establishing and maintaining an ice access/supply road, and
- outlines the plans for QC during construction and monitoring during drilling, activities key to ensuring the safety of the wells and the operation.

Sandwell Engineering Inc.
CLIENT: Phillips Alaska Inc.
REPORT DATE: September 29, 2000

McCovey Ice Island – Island Design Report

Project Time Line and Effects of Ice Movement

Date	Ph	Major Tasks	Effect of Ice Movement less than 20’	Effect of Ice Movement 20’ to 200’	Effect of Ice Movement greater than 200’
11/24 to 12/1	Pre Grounding	Ice Road to Reindeer Isl.	Minor repairs to road or re-routing of road.	Repairs to or re-routing of road.	May have to re-establish road once ice re-forms.
12/1 to 12/20	Pre Grounding	Ice Road Reindeer to McCovey & site preparation	Repairs to or re-routing of road. No effect on island.	Repairs to or re-routing of road.	Loss of ice road & island site for offshore movement >2000’ Or, formation of extensive ice rubble at or near island site to our advantage.
12/20 to 01/15	Pre Grounding	Spraying prior to grounding	Repairs to or re-routing of road. If leads occur at island pump moves delayed.	Repairs to or re-routing of road If lead occurs at island pump moves delayed or access denied. Possibility of damage to island or island being displaced from original location.	Loss of ice cover & road for movement >2000’ Island may be displaced too far and lost. Extensive rubble may form at or near site to advantage with extreme movement.
01/15 to 02/01	Post Grounding	Spraying post grounding	Repairs to or re-routing of road. If lead occurs at island pump moved delayed.	Repairs to or re-routing of road. If lead occurs at island pump moves delayed. Ice rubbling at island perimeter	Ice rubbling at island perimeter. Loss of ice cover & road for movement > 2000’
02/01 to 02/07	Post Grounding	Island Verification Transport of rig to island.	Possible delay in rig move. Minor ice rubbling at island	Repairs to or re-routing of road. Likely delay in rig move. Ice rubbling at island perimeter.	Movements unlikely
02/07 to 05/01	Drilling	Drilling and testing	Repairs to road. Minor ice rubbling at island	Repairs to or re-routing of road. Ice rubbling at island perimeter.	Movements unlikely

Sandwell Engineering Inc. CLIENT: Phillips Alaska Inc. REPORT DATE: September 29, 2000					
McCovey Ice Island – Island Design Report					
05/01 to 05/15		Transport of rig etc. to shore. Site decommission -ing	Possible delay in rig move. Minor ice rubbling at island.	Repairs to or re-routing of road. Likely delay in rig move. Ice rubbling at island perimeter.	Movements unlikely.